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NATIVE SPECIES INVESTIGATIONS

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Subproject 1: Yellowstone cutthroat trout trends
Subproject 2: Yellowstone cutthroat trout maturity studies

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ANNUAL PERFORMANCE REPORT
SUBPROJECT #1: YELLOWSTONE CUTTHROAT TROUT TREND

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ABSTRACT

We compared estimates of population abundance and size structure of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* (YCT) derived by electrofishing 77 stream and river segments across southeastern Idaho in the 1980s and again in 1999-2000 to test whether populations of YCT had changed. Sites sampled in the 1980s were relocated in 1999-2000 using maps, photographs, and/or finding original reach-boundary stakes, so that the exact same reach of stream was sampled during both time periods. Abundance of YCT >10 cm did not change between the 1980s and 1999-2000, averaging 40.0 and 41.3 fish/100 m of stream, respectively. The proportion of the total catch of trout that YCT comprised also did not change, averaging 80.0% in the 1980s and 79.0% in 1999-2000. At the 48 sites where size structure could be estimated for both periods, there was a slight decline in the proportion of fish 10-20 cm (73.9% vs. 66.2%) and a slight increase in the proportion of fish 30-40 cm (7.5% vs. 11.8%). The size structure shift was at least partly a result of restrictive size and bag limit regulations designed to reduce YCT harvest throughout much of southeastern Idaho. Yellowstone cutthroat trout >10 cm were not captured at four of the 77 sites that originally contained them in the 1980s. The number of sites that contained rainbow trout or rainbow/cutthroat hybrids (RBT/HYB) rose from 21 to 38, but the average proportion of the catch that RBT/HYB comprised did not increase measurably (6.5% in 1980s and 7.1% in 1999-2000). Although the distribution and abundance of YCT has been substantially reduced in Idaho over the last century, our results suggest that YCT abundance in Idaho has remained stable for the last 10-20 years. The expanding distribution of RBT/HYB calls for additional monitoring and perhaps increased or alternative management actions.

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INTRODUCTION

Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* (YCT) are more abundant and have a wider distribution than any other nonanadromous cutthroat trout subspecies (Varley and Gresswell 1988; Behnke 1992). Since European settlement of the western United States, YCT have experienced a considerable decline in abundance and distribution in portions of their historical range (Gresswell 1995; May 1996; Kruse et al. 2000). Factors that have contributed to this decline include hybridization with or displacement by nonnative trout, past overharvest from sport fishing, and habitat alterations due to water storage and diversion, grazing, mineral extraction, and timber harvest (Thurow et al. 1988, Varley and Gresswell 1988; Gresswell 1995). Such declines led to a petition in August 1998 for YCT protection under the Endangered Species Act (ESA).

The extent of this decline, however, remains unclear because most previous assessments of YCT status have largely been qualitative and based on professional judgment (Thurow et al. 1988; Varley and Gresswell 1988; May 1996). May (1996) suggested that viable populations remain in only 43% of the historical range in Idaho, but this approach required major assumptions about which streams were originally occupied. Assessments that have been quantitative have focused on the proportion of historical range now occupied. For example, Kruse et al. (2000) found that 26% of the 104 trout-bearing streams in the Greybull and Shoshone drainages in Wyoming outside of Yellowstone National Park contained genetically pure YCT.

However, the decline in species range is a common phenomenon across the American landscape and by itself, does not provide justification for ESA listing if remaining populations are stable or increasing and secure. Consequently, in 1999 and 2000, Idaho Department of Fish & Game (IDFG) personnel revisited numerous locations throughout the historical range of YCT in southeastern Idaho that were sampled between 1980 and 1989 to investigate whether YCT populations appeared to be declining over the past 10-20 years.

OBJECTIVE

1. Describe changes in YCT populations between the 1980s and 1999-2000 by comparing estimates of abundance and size structure from paired locations across southern Idaho.

STUDY AREA

The native distribution of YCT in Idaho includes the Snake River drainage upstream from Shoshone Falls and a now extinct population from Waha Lake (Behnke 1992). The upper Snake River basin in Idaho has a semiarid climate and contains watersheds that exceed 3,000 m in elevation. Discharge in most tributaries is driven by snowmelt and peaks between April and June, but flows in most mainstem rivers are controlled by reservoir releases of irrigation water and often peak during the summer. Most streams and rivers are relatively productive for the Rocky Mountains, with conductivity exceeding 200 µS/cm. Mountain whitefish *Prosopium williamsoni* is the only other native salmonid present, but rainbow trout *O. mykiss*, brook trout

Salvelinus fontinalis, and brown trout *Salmo trutta* have been introduced throughout much of southeastern Idaho. Two species of Cottidae, three species of Catostomidae, and four species of Cyprinidae are also indigenous to the basin. The study area was comprised of a large number of individual sampling sites from six main subbasins across southeastern Idaho that were originally sampled during the 1980s with electrofishing gear to obtain YCT abundance estimates for general fish management purposes (Figure 1). Sites ranged from 49-7300 m in length, from 2-79 m in width, from 1457-2097 m in elevation, and from 1^{st}-6^{th} in stream order.

METHODS

In 1999 and 2000, IDFG personnel involved in the original sampling returned to identify the old sites and locate reach boundaries. Only those sites where survey boundaries could clearly be determined from surveyor's stakes, field notes, maps, and photographs were selected for resampling. A total of 77 sites were identified for paired sampling comparisons (Figure 1). To minimize the effect that seasonal changes can have on fish abundance (Decker and Erman 1992), sampling was replicated as close to the original calendar date as possible. Sixty-five percent of the sites were resampled within two weeks of the original calendar date; 88% were within four weeks, and all were within six weeks. All sampling occurred between mid-July and early November under baseflow conditions, with the majority (71%) sampled in September and October.

In streams less than about 4 m average wetted stream width, two- or three-pass electrofishing removals were made using backpack-mounted units and pulsed DC. Maximum likelihood estimates of abundance and 95% confidence intervals were made using the MicroFish software package (Van Deventer and Platts 1989). Where all YCT were captured on the first pass, confidence intervals were not estimated. For larger streams and rivers, mark-recapture electrofishing passes were made using a canoe- or boat-mounted unit and DC or pulsed DC. Log likelihood estimates of abundance and 95% confidence intervals were made using the Mark Recapture for Windows software package (Montana Fish, Wildlife, and Parks 1997). Mark-recapture estimates were made for each 10 cm size class and summed for an estimate of the total number of YCT present. Methods used to collect fish and to estimate abundance in 1999-2000 were meticulously replicated at each site from methods used in the 1980s with the following three exceptions: at the lower and upper sites on the Blackfoot River, depletion estimates were made in 1986 and mark-recapture estimates were made in 2000; and, at the upper site on Willow Creek, a mark-recapture estimate was made in 1984, but a depletion estimate was made in 2000. Abundance estimates were made only for YCT greater than 10 cm and were converted to numbers of YCT/100 m of stream using measured reach lengths. No estimates were made for other salmonids. Before being returned to the study reach, fish were measured for total length (mm) and weight (g).

We calculated the proportion of trout caught that were YCT and rainbow trout or hybrids (hereafter RBT/HYB) as the proportion of the total catch of trout greater than 10 cm. We also calculated the proportion of YCT that were 10-20 cm, 20-30 cm, 30-40 cm, and >40 cm in total length, and compared the proportions between periods to test for changes in YCT size structure. In the size structure analysis we only included those sites where more than 20 YCT were caught during both time periods at a site. We tested whether YCT abundance, proportion of catch, or size structure had changed from the 1980s to 1999-2000 using paired *t*-tests (Zar 1996) and 95% confidence intervals around $\bar{d}$, the difference between means (Johnson 1995).

Proportional data are known to be binomially rather than normally distributed. However, data do not need to be normally distributed to apply the *t*-test; only the means need to be, and that property is assured by the Central Limit Theorem (Johnson 1995). Thus we made no transformation to the percentage data.

RESULTS

The abundance of YCT at the 77 paired sites was not statistically different between time periods, averaging 40.0 fish/100 m of stream in the 1980s compared to 41.3 in 1999-2000 ($\bar{d}$ = 1.3 ± 8.8; t = 0.332; P = 0.741; Table 1). Abundance was lower at 31 locations and higher at 44 locations. We also found no differences between the 1980s and 1999-2000 within individual drainages (Table 2), but sample size was low for most comparisons. Higher abundance was observed at two of four sites in the Raft River/Goose Creek drainages, four of 11 sites in the Portneuf River drainage, eight of 11 sites in the Blackfoot River drainage, one of five sites in the Willow Creek drainage, 29 of 41 sites in the South Fork Snake River drainage, and none of the four Teton River sites (Figure 2). At five locations, no YCT >10 cm in length were captured in 1999-2000 where they had been captured in the 1980s.

YCT made up a similar proportion of the catch in the 1980s (80.0%) as in 1999-2000 (79.0%) ($\bar{d}$ = -1.0 ± 7.3; t = -0.271; P = 0.787; Table 1). YCT made up 100% of the catch at 32 sites in the 1980s compared to 26 sites in 1999-2000. The proportion of RBT/HYB in the catch also did not change (6.5% in the 1980s vs. 7.1% in 1999-2000; $\bar{d}$ = 0.6 ± 3.9; t = 0.297; P =0.767), but the number of locations where RBT/HYB were present rose from 21 to 38 sites. RBT/HYB made up less than 10% of the catch at 67 sites in the 1980s and 59 in 1999-2000.

The YCT were slightly larger in 1999-2000 than in the 1980s (Table 1). At the 48 sites where YCT sample sizes were large enough to calculate size structure for both periods, there was a slight decrease in the proportion of fish 10-20 cm in length (73.9% vs. 66.2%; $\bar{d}$ = -7.7 ± 5.0; t = -3.103; P = 0.003), and a slight increase in fish 30-40 cm (7.5% vs. 11.8%; $\bar{d}$ = 4.3 ± 3.9; t = 2.201; P = 0.033). The percentages did not change for fish 20-30 cm (16.0% vs. 17.7%; $\bar{d}$ = 1.8 ± 4.9; t = 0.722; P = 0.474) or for fish >40 cm (2.6% vs. 4.2%; $\bar{d}$ = 1.6 ± 2.0; t = 1.597; P = 0.117). The largest change occurred in the Teton River sites, where the percentage of fish 10-20 cm decreased from an average of 48% to 8%, and fish >30 cm increased from an average of 8% to 64%. However, even with the exclusion of the Teton River data, the proportion of fish 10-20 cm still decreased slightly from 76.3% to 71.6% ($\bar{d}$ = -4.7 ± 4.5; t = -2.146; P = 0.038).

DISCUSSION

The abundance and distribution of YCT rangewide in Idaho has undoubtedly declined over the last century. For example, we know of only 12 streams in the entire Henry's Fork Snake River drainage that currently contain YCT, but historically they were found throughout the drainage. Similarly, YCT are scarce across much of the Raft River, Goose Creek, Bannock Creek, and Rock Creek drainages, although assessing the historical distribution or abundance of YCT in these drainages is problematic because they currently contain and probably historically contained few perennial streams. In the mainstem of the Snake River from Shoshone Falls to Idaho Falls, YCT are either displaced or persisting at low densities. Because our samples were not selected at random but were originally established in areas where YCT were present in the 1980s, we are cautious about quantitatively extrapolating the results of this study throughout southeast Idaho. Nevertheless, the broad geographic nature of our monitoring effort suggests that, in general, YCT abundance over the last 10-20 years in Idaho has remained relatively stable.

The distribution of YCT in Idaho also appears to have remained relatively stable from the 1980s to present as well. We failed to capture YCT >10 cm at only five sites that previously contained them. The site on Jensen Creek in 1986 included a large beaver pond that, by 1999, had breached and become a shallow uncomplex stream reach that nonetheless contained several YCT <10 cm, and YCT >10 cm were present both upstream and downstream of the site. At the lower site on Toponce Creek in 1980, only one YCT was captured in a degraded stream reach that was full of cyprinids (dace and chubs). In 2000, the cyprinids were still present but we did not catch any YCT, although YCT were present in most of this stream above the study reach. The status of YCT in the remaining three streams is unknown at this time, but the reach lengths sampled at these three sites preclude definitive conclusions regarding YCT presence/absence. Overall, YCT appear to be well distributed in Idaho streams. Meyer and Lamansky (2001) randomly sampled 61 and 76 stream sites (usually 100 m in length) throughout the Portneuf River and Teton River drainages, respectively, and YCT were present in 63% and 73% of those sites that contained fish.

We did not observe a statistically significant decline in average YCT abundance in any individual drainage, but sample sizes were too small to perform meaningful analysis in most drainages. It does appear that abundance declined in the Teton River and Willow Creek drainages, but there was no decline in biomass. Abundance of YCT declined in the Teton River at all four locations, from an average of 16.1 to 8.0 fish/100 m. However, because of the tremendous increase in the size of fish between time periods in the Teton River, YCT biomass actually increased from an average of 5.8 to 7.3 kg/ha (W. Schrader, unpublished data). Similarly, YCT abundance in the Willow Creek drainage declined from an average of 40.4 to 15.5 YCT/100 m, but biomass rose from an average of 41.7 to 56.4 kg/ha (K. Meyer, unpublished data). We chose to express YCT population strength by abundance rather than biomass for the purposes of assessing population declines, and the abundance comparison we made may have been a more conservative indicator of YCT stock strength between time periods than biomass would have been.

The increase in larger YCT between time periods was likely due at least partly to restrictions in fishing regulations. Restricted harvest regulations for YCT were initially implemented in the South Fork Snake River in 1984. By 1990, some form of angler harvest restrictions were in place for YCT in all major drainages in Idaho. Restrictions have focused on protecting spawning-size fish, and have included size limits, bag limits, and delaying the fishing season opener in spawning streams (IDFG 2000). The restrictions appear to have resulted in more larger fish, although changing social attitudes regarding fish harvest may have played a role as well (Elle et al. 1987; Schmetterling and Long 1999).

Rainbow trout or hybrids were present in half of the comparison sites in 1999-2000 and are of concern. However, their distribution does not necessarily reflect the extent of YCT hybridization occurring in Idaho. For example, in the Portneuf River drainage, RBT/HYB (determined by visual identification) were present in 1999-2000 in 73% of the sites used in this study (Table 1). However, in 61 randomly distributed sites in the Portneuf River drainage sampled by Meyer and Lamansky (2001), RBT/HYB were present in only 11% of the sites and only 17% of the sites that contained YCT. Similarly, in 76 randomly distributed sites sampled by Meyer and Lamansky (2001) in the Teton River drainage, RBT/HYB were found in only 8% of the sites that contained fish and only 8% of the sites that contained YCT. This discrepancy may be a reflection of the prior sampling design used in our pre-post comparison. In the 1980s, sites were established in the lower segments of streams and in rivers where more angling pressure existed, where more stocking of rainbow trout occurred, and therefore where subsequent hybridization was more likely to develop.

Nevertheless, we agree with Kruse et al. (2000) in arguing that controlling hybridization is an important factor in assuring the long-term persistence of YCT. Steps are currently being taken in Idaho, especially in Henry's Lake, the South Fork Snake River, and the Blackfoot River, to minimize the presence of RBT/HYB. At Henry's Lake, we are selecting only "pure" YCT for IDFG broodstock based on phenotypic characters hatchery personnel verified by mtDNA testing, and have implemented a sterile hybrid stocking program (J. Dillon, IDFG, personal communication). On the South Fork Snake and Blackfoot rivers, RBT/HYB are being removed via large-scale tributary trapping of migrating spawners, electrofishing removals, and liberalized regulations for RBT/HYB to encourage angler harvest. In addition, IDFG has adopted a policy dictating that rainbow trout stocked in drainages that currently contain YCT must be sterile triploids (Dillon et al. 2000).

Because salmonid populations often fluctuate greatly, both temporally (Platts and Nelson 1988; House 1995) and spatially (Milner et al. 1993), it can be difficult to detect changes or trends in salmonid populations (e.g., Rieman and Myers 1997). That our sampling during both time periods occurred in more than one year, and that our sample size was relatively large, should help eliminate the difficulty that spatial and temporal fluctuations in fish abundances introduce to before-after analysis. Platts and Nelson (1988) found that population characteristics of cutthroat trout fluctuated greatly over space and time, but suggested that a study design such as ours, with paired-comparisons incorporating more than one year of sampling, is more likely to detect changes if they occurred.

In conclusion, YCT numbers in Idaho are not in decline but instead appear relatively stable throughout much of their historical range, at least at the widely distributed sites we sampled. Idaho Department of Fish and Game management actions to reduce the threat of genetic introgression are widespread and ongoing (Dillon et al. 2000; IDFG 2000). Surveys of the remaining subbasins in the upper Snake River basin for YCT are being initiated by state and federal agencies. By discontinuing the stocking of fertile hatchery rainbow trout and continuing to implement fishing regulations and projects designed to reduce or eliminate RBT/HYB, the wild YCT populations in Idaho appear to be relatively secure.

RECOMMENDATIONS

1. Continue to monitor YCT populations at the study sites, and consider adding additional monitoring sites across the range to provide better coverage in drainages with few current long-term monitoring sites.

2. Continue inventorying YCT throughout southeastern Idaho, especially in areas where existing data is sparse and where YCT appear to be in decline.

3. Continue projects designed to reduce or eliminate RBT/HYB, especially in the Teton, South Fork Snake, and Blackfoot river drainages where YCT appear to be most threatened by hybridization.

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Table 1. Temporal comparison of 77 Yellowstone cutthroat trout (fish >10 cm) estimates of abundance (fish/100 m), relative composition, and size structure across the historical range in Idaho between the 1980s and 1999-2000. Stream numbers correspond to Figure 1. NA refers to Not Available.

Stream		Study site length	Type of esti-	Abundance (fish/100 m)							1980s		1999-2000		Percent of YCT catch per size category (cm)							
				1980s			1999-2000			Differ-	%	%	%	%	1980s				1999-2000			
No.	Name	(m)	mate[a]	N	95% CI	Year	N	95% CI	Year	ence	YCT	RBT/HYB	YCT	RBT/HYB	10-20	20-30	30-40	>40	10-20	20-30	30-40	>40
								Raft River/Goose Creek drainages														
1	Birch Creek	80	D	1.3	NA	1987	0.0	NA	2000	-1.3	50	0	0	0								
2	Cold Creek	60	D	5.0	5.0-10.3	1987	0.0	NA	2000	-5.0	100	0	0	40								
3	Eightmile Creek	82	D	6.1	6.1-7.9	1986	23.2	23.2-24.5	2000	17.1	100	0	100	0								
4	Trout Creek	110	D	0.9	NA	1987	7.0	NA	2000	6.1	8	92	89	11								
								Portneuf River drainage														
5	Pebble Creek	207	D	44.0	42.5-46.6	1986	14.0	NA	2000	-30.0	75	24	94	7	92	8	0	0	97	3	0	0
6	Pebble Creek	98	D	32.6	31.6-36.4	1986	44.8	44.8-46.5	1999	12.2	80	15	86	14	90	10	0	0	68	30	2	0
7	Pebble Creek	104	D	77.9	75.0-83.3	1986	44.2	44.2-45.1	1999	-33.7	72	3	77	23	97	3	0	0	74	26	0	0
8	Pebble Creek NF	133	D	34.7	34.7-35.6	1986	15.1	NA	1999	-19.6	100	0	100	0	100	0	0	0	95	5	0	0
9	Big Springs Creek	105	D	25.8	25.3-27.6	1986	25.8	25.8-27.7	1999	0.0	63	7	93	7					96	4	0	0
10	King Creek	70	D	7.1	7.1-9.3	1986	0.0	NA	2000	-7.1	100	0	0	0								
11	Toponce Creek	180	D	0.6	NA	1986	0.0	NA	2000	-0.6	100	0	0	0								
12	Toponce Creek	89	D	6.7	NA	1986	0.2	NA	2000	-6.5	7	91	13	3								
13	Toponce Creek, MF	80	D	2.5	NA	1986	15.0	NA	2000	12.5	3	74	16	84								
14	Toponce Creek, SF	99	D	133.5	NA	1987	146.9	143.4-152.1	2000	13.4	88	12	95	5	74	26	0	0	83	17	0	0
15	Toponce Creek, SF	113	D	29.2	29.2-30.3	1987	47.0	44.0-53.6	2000	17.8	94	6	98	2	91	9	0	0	93	7	0	0
								Blackfoot River drainage														
16	Blackfoot River	4720	D/MR	0.8	0.8-1.0	1988	17.0	13.3-20.7	2000	16.2	88	0	85	13	14	50	14	21	15	53	5	27
17	Blackfoot River	1712	MR	16.1	6.9-25.3	1988	36.1	31.3-40.9	2000	20.0	99	1	83	17	91	6	3	0	95	2	1	2
18	Blackfoot River	1760	D/MR	5.8	5.5-6.3	1988	11.4	8.4-14.4	2000	5.6	97	2	68	31	35	27	25	13	43	8	18	31
19	Diamond Creek	180	D	8.5	6.4-7.1	1988	10.6	10.6-11.8	2000	2.1	89	0	100	0								
20	Diamond Creek	147	D	130.6	125.9-135.6	1980	61.9	61.9-63.3	2000	-68.7	98	0	90	10	94	6	0	0	92	8	0	0
21	Diamond Creek	150	D	174.1	170.1-178.8	1980	61.3	61.3-62.5	2000	-112.8	99	0	91	9	98	2	0	0	97	3	0	0
22	Diamond Creek	165	D	23.7	22.5-26.9	1987	64.4	63.8-66.1	2000	40.7	90	0	91	9	97	3	0	0	99	1	0	0
23	Diamond Creek	87	D	10.3	10.3-13.8	1987	43.7	43.7-44.0	2000	33.4	80	0	91	10					100	0	0	0
24	Diamond Creek	75	D	50.7	50.7-52.5	1987	37.9	36.4-44.5	2000	-12.8	97	0	77	23	97	3	0	0	96	0	4	0
25	Diamond Creek	165	D	3.0	22.4-23.8	1988	31.3	26.9-38.4	2000	28.3	88	0	62	38	95	5	0	0	98	2	0	0
26	Sheep Creek	161	D	5.0	NA	1987	6.2	6.2-7.2	2000	1.2	100	0	100	0								
								Willow Creek drainage														
27	Willow Creek	886	MR	27.1	15.6-38.6	1984	4.7	1.8-7.6	2000	-22.4	66	0	85	0	22	67	7	3	14	36	45	5
28	Willow Creek	571	MR/D	75.0	52.0-98.0	1984	23.3	18.7-28.5	2000	-51.7	64	0	92	0	76	23	1	0	51	45	4	0
29	Brockman Creek	93	D	7.5	7.5-8.6	1983	26.9	24.7-33.5	2000	19.4	78	0	100	0					4	30	65	0
30	Corral Creek	71	D	64.8	52.1-88.6	1982	6.3	6.3-8.2	2000	-58.5	100	0	100	0	100	0	0	0				
31	Corral Creek	127	D	27.6	27.6-29.1	1982	14.6	14.6-16.2	2000	-13.0	100	0	100	0	97	3	0	0	100	0	0	0

Table 1. (Continued.)

Stream		Study site length	Type of esti-	Abundance (fish/100 m)							1980s		1999-2000		Percent of YCT catch per size category (cm)							
				1980s			1999-2000			Differ-	%	%	%	%	1980s				1999-2000			
No.	Name	(m)	mate[a]	N	95% CI	Year	N	95% CI	Year	ence	YCT	RBT/HYB	YCT	RBT/HYB	10-20	20-30	30-40	>40	10-20	20-30	30-40	>40
	Mainstem Snake River drainage																					
32	Snake River	7300	MR	7.6	2.1-45.8	1988	8.4	1.7-50.5	2000	0.8	37	14	20	8	1	31	54	14	4	45	36	15
	South Fork Snake River drainage																					
33	Snake River, SF	4800	MR	19.2	3.8-87.9	1989	28.2	6.9-101.4	1999	9.0	33	1	23	1	3	24	51	23	5	22	63	11
34	Snake River, SF	2900	MR	56.8	12.7-179.9	1989	71.9	16.1-178.8	2000	15.1	50	0	28	1	2	19	59	20	6	32	55	7
35	Snake River, SF	4900	MR	165.9	46.2-293.6	1989	208.7	36.4-533.6	1999	42.8	89	4	63	20	2	8	78	13	4	34	59	3
36	Burns Creek	85	D	56.5	52.9-64.7	1980	37.6	30.6-55.4	2000	-18.9	100	0	68	8	89	11	0	0	96	0	4	0
37	Burns Creek	86	D	7.0	7.0-8.4	1980	31.4	31.4-31.9	2000	24.4	100	0	84	6					63	30	7	0
38	Pine Creek	66	D	51.5	50.0-56.7	1980	69.7	68.2-75.2	2000	18.2	97	0	92	8	91	9	0	0	98	2	0	0
39	Pine Creek	90	D	77.8	77.8-79.4	1988	24.4	24.4-26.8	2000	-53.4	100	0	100	0	84	13	3	0	100	0	0	0
40	Pine Creek	74	D	155.4	134.7-182.4	1980	155.4	129.7-184.2	2000	0.0	100	0	97	3	97	3	0	0	87	12	1	0
41	Pine Creek	80	D	53.8	53.7-55.9	1988	82.5	82.5-84.1	2000	28.7	100	0	92	8	83	14	2	0	94	6	0	0
42	Pine Creek, NF	72	D	22.3	22.3-24.0	1982	18.1	18.1-18.9	2000	-4.2	100	0	100	0								
43	Pine Creek, NF	80	D	43.8	43.8-46.8	1981	8.8	8.8-9.8	2000	-35.0	100	0	88	13	91	9	0	0				
44	Rainey Creek	160	D	1.3	NA	1980	38.8	32.5-49.3	2000	37.5	22	0	95	0					73	25	2	0
45	Rainey Creek	123	D	6.5	6.5-9.2	1980	4.1	4.1-6.7	2000	-2.4	42	0	100	0								
46	Rainey Creek	167	D	9.0	9.0-10.2	1980	40.7	40.7-41.5	2000	31.7	68	0	76	2					41	38	20	1
47	Fall Creek	133	D	12.8	12.8-14.7	1988	60.5	53.5-71.0	2000	47.7	100	0	100	0					60	37	3	0
48	Bear Creek	246	D	17.9	10.2-41.5	1980	71.5	69.9-73.7	2000	53.6	100	0	99	1	100	0	0	0	94	5	0	1
49	Elk Creek	146	D	24.7	19.2-37.7	1980	36.3	35.6-38.6	2000	11.6	100	0	100	0	96	4	0	0	92	8	0	0
50	Big Elk Creek	97	D	8.2	8.2-9.2	1980	33.0	32.0-37.1	2000	24.8	100	0	100	0					16	9	53	22
51	Big Elk Creek	146	D	19.9	17.1-27.2	1980	61.3	58.0-66.4	2000	41.4	100	0	100	0	12	44	36	8	4	11	62	24
52	McCoy Creek	375	MR	71.5	NA	1986	45.1	40.2-50.0	2000	-26.4	99	1	97	1	93	6	0	1	80	16	4	1
53	McCoy Creek	388	MR	108.8	NA	1986	117.5	79.1-155.9	2000	8.7	100	0	100	0	95	5	0	0	93	5	2	0
54	McCoy Creek	144	D	52.9	50.1-57.9	1986	56.9	54.9-60.8	1999	4.0	100	0	100	0	94	6	0	0	91	8	1	0
55	Jensen Creek	49	D	162.6	91.5-303.7	1986	0.0	NA	1999	-162.6	100	0	0	0	88	12	0	0				
56	Fish Creek	79	D	48.4	44.6-57.2	1986	167.0	163.0-172.7	1999	118.6	100	0	100	0	100	0	0	0	46	53	1	0
57	Fish Creek	92	D	43.5	42.4-47.4	1986	90.2	85.7-97.3	1999	46.7	100	0	100	0	95	3	3	0				
58	Barnes Creek	99	D	24.2	24.2-25.7	1986	33.6	28.3-44.8	1999	9.4	100	0	100	0	88	13	0	0	93	7	0	0
59	Barnes Creek	76	D	7.9	7.9-9.5	1986	10.5	NA	1999	2.6	100	0	100	0								
60	Clear Creek	122	D	61.5	37.7-106.6	1986	31.1	30.3-34.2	1999	-30.4	100	0	100	0	93	7	0	0	95	5	0	0
61	Iowa Creek	97	D	25.8	25.8-27.2	1986	31.3	31.3-33.4	2000	5.5	100	0	100	0	96	4	0	0	100	0	0	0
62	Jackknife Creek	107	D	29.0	29.0-29.7	1987	14.0	14.0-15.1	1999	-15.0	97	0	100	0	81	16	3	0				
63	Tincup Creek	155	D	62.8	54.4-73.9	1987	76.8	76.8-83.4	1999	14.0	98	1	98	0	88	12	0	0	42	47	11	0
64	Tincup Creek	117	D	129.1	124.8-135.1	1987	64.1	62.4-68.3	1999	-65.0	97	1	100	0	93	7	0	0	80	17	3	0
65	Tincup Creek	100	D	66.0	65.0-69.2	1987	21.0	21.0-22.5	1999	-45.0	100	0	100	0	97	3	0	0	81	14	5	0
66	Bear Canyon Creek	52	D	87.8	87.8-91.6	1987	32.7	32.7-34.8	1999	-55.1	100	0	94	6	100	0	0	0				
67	Stump Creek	441	MR	49.2	34.0-64.4	1986	93.9	86.0-101.8	2000	44.7	81	0	86	0	86	13	1	0	67	30	2	0
68	Horse Creek	86	D	40.6	40.6-42.8	1986	70.7	70.7-72.7	1999	30.1	100	0	94	0	86	14	0	0	90	10	0	0
69	Crow Creek	309	MR	4.5	2.6-6.4	1986	18.1	5.8-45.5	2000	13.6	43	0	94	0					24	41	34	0
70	Crow Creek	111	D	84.7	82.0-89.8	1986	117.1	117.1-118.8	1999	32.4	0	0	93	0	79	21	0	0	83	17	0	0
71	Sage Creek	215	D	17.2	16.4-19.0	1987	31.0	31.0-31.4	1999	13.8	16	0	22	0	72	28	0	0	34	64	2	0
72	Deer Creek	157	D	40.9	31.3-57.6	1986	78.5	78.5-79.5	1999	37.6	83	0	93	1	75	23	3	0	80	19	1	0
73	White Dugway Creek	84	D	13.1	13.1-16.1	1986	6.0	NA	1999	-7.1	92	0	100	0								

Table 1. (Continued.)

Stream		Study site length (m)	Type of esti-mate[a]	Abundance (fish/100 m)							1980s		1999-2000		Percent of YCT catch per size category (cm)							
				1980s			1999-2000			Differ-ence	%	%	%	%	1980s				1999-2000			
No.	Name			N	95% CI	Year	N	95% CI	Year		YCT	RBT/HYB	YCT	RBT/HYB	10-20	20-30	30-40	>40	10-20	20-30	30-40	>40
										Teton River drainage												
74	Teton River	4900	MR	6.4	1.3-59.8	1987	5.6	2.2-24.8	1999	-0.8	17	66	44	37	45	43	8	5	2	40	39	19
75	Teton River	5500	MR	8.4	2.7-42.0	1987	6.9	2.4-29.3	2000	-1.5	27	48	57	29	42	51	5	2	4	15	56	26
76	Teton River	7100	MR	18.7	4.6-72.8	1987	8.4	2.3-38.3	2000	-10.3	46	32	58	27	50	43	6	1	9	20	50	22
77	Teton River	5800	MR	30.9	5.3-159.2	1987	11.0	3.2-39.4	1999	-19.9	54	7	56	11	53	42	4	1	16	41	32	11
	AVERAGE			**40.9**			**41.2**			**0.3**	**80.0**	**6.5**	**79.0**	**7.1**	**76.0**	**14.9**	**6.8**	**2.3**	**64.2**	**18.7**	**13.2**	**3.9**

[a] Multiple-pass depletion (D) or mark-recapture (MR)

Table 2. Mean abundance of Yellowstone cutthroat trout and *t*-test summary statistics by drainage from the 1880s and 1999-2000 in Idaho.

Drainage	n	Mean Abundance (fish/100m) 1980s	1999-2000	$\bar{d}$ ± 95% CI	*t* Statistic	*P*-value
Raft River/Goose Creek	4.0	3.3	7.6	4.3 ± 15.5	- 0.87	0.45
Portneuf River	11.0	35.9	32.1	- 3.8 ± 11.9	0.71	0.50
Blackfoot River	11.0	39.0	34.7	- 4.3 ± 31.3	0.30	0.77
Willow Creek	5.0	40.4	15.2	- 25.2 ± 39.1	1.76	0.15
South Fork Snake River	41.0	49.8	55.9	6.1 ± 13.8	- 0.88	0.38
Teton River	4.0	16.1	8.0	- 8.1 ± 14.3	1.81	0.17
Total	**77.0**	**40.9**	**41.2**	**0.3 ± 8.7**	**- 0.05**	**0.96**

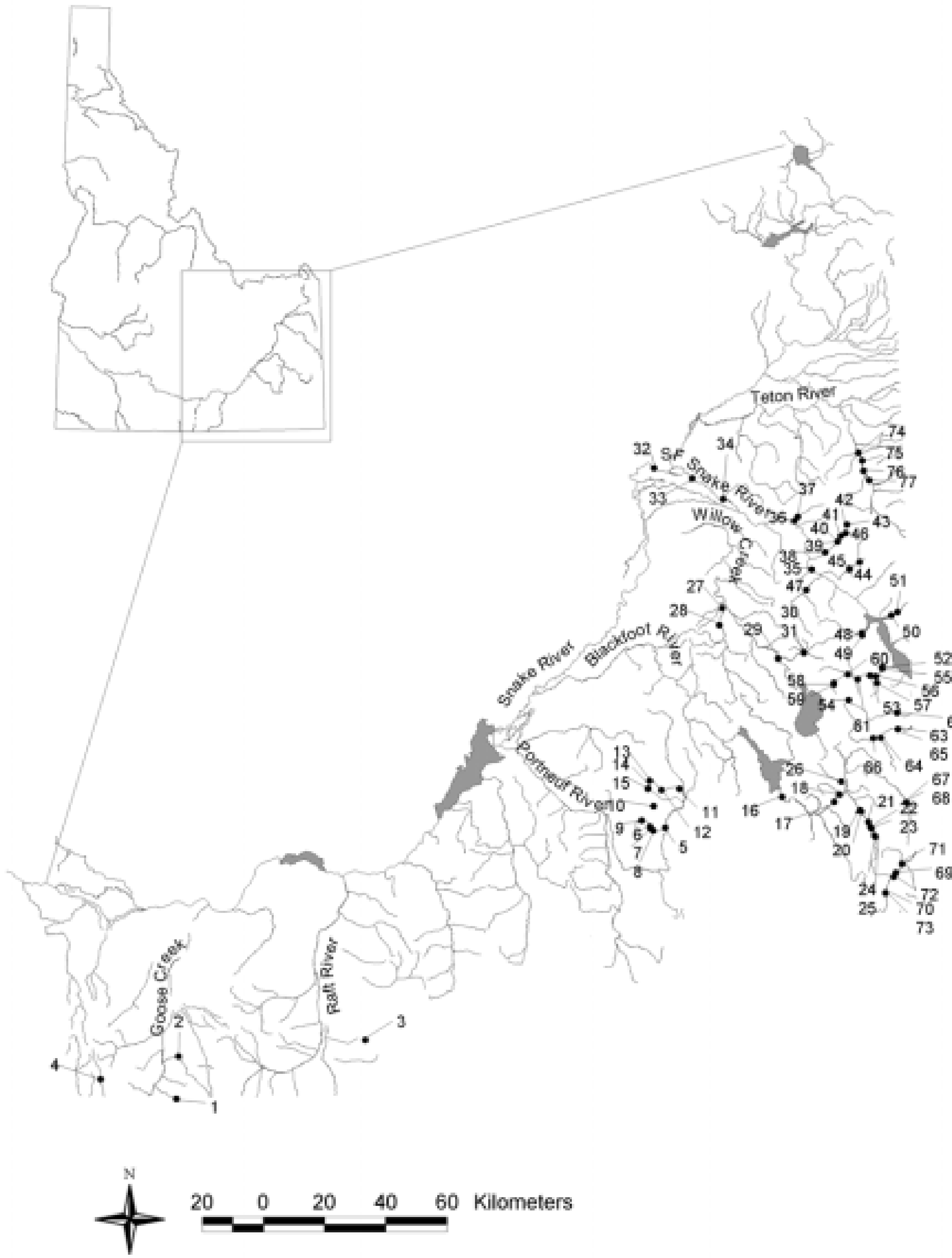

Figure 1. Locations of study sites sampled in the 1980s and again in 1999-2000 across the historical range of Yellowstone cutthroat trout in Idaho. Numbers correspond to Table 1.

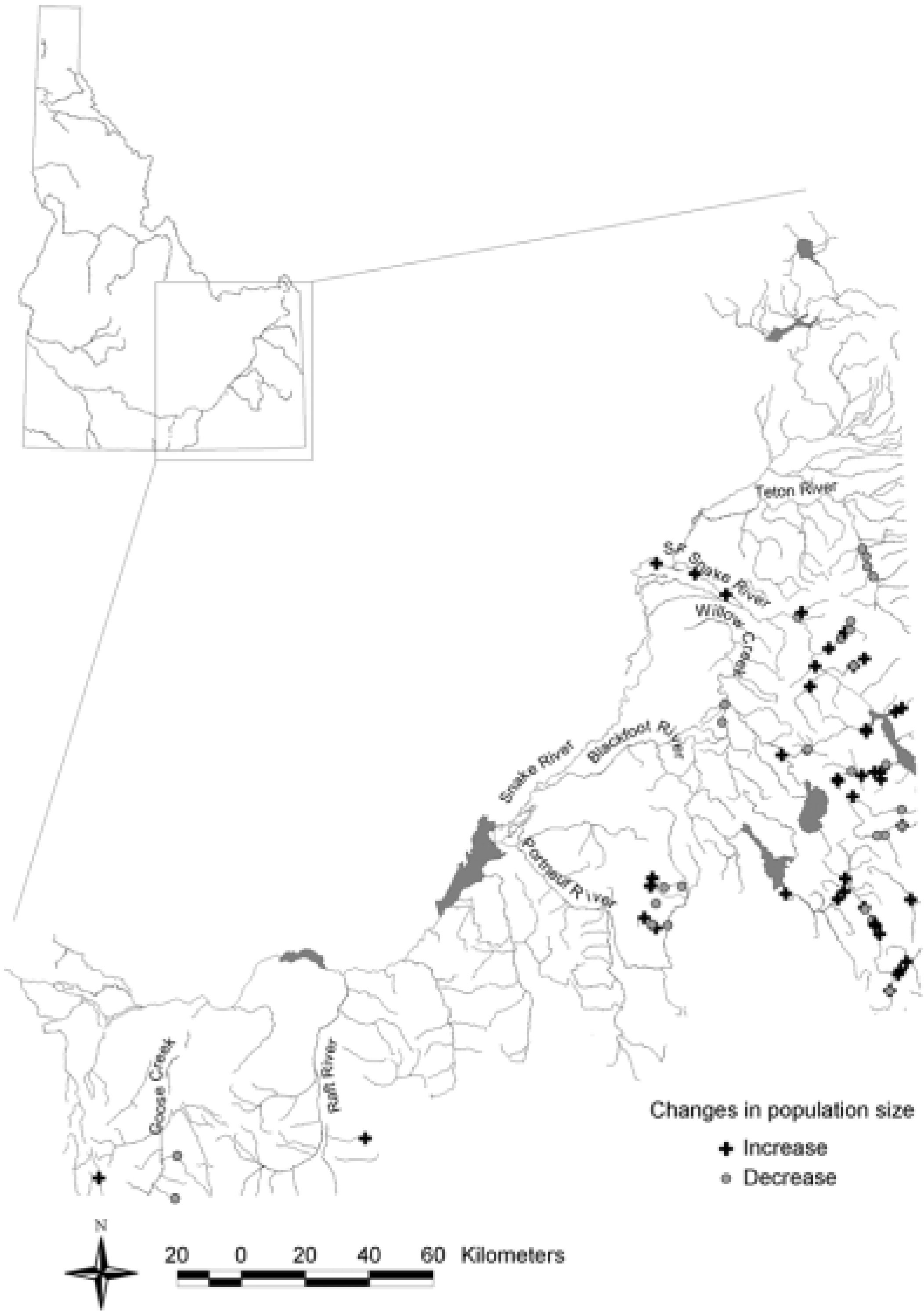

Figure 2. Study sites where Yellowstone cutthroat trout abundance increased (solid "+" sign) or decreased (shaded circles) between the 1980s and 1999-2000 across their historical range in Idaho.

ANNUAL PERFORMANCE REPORT
SUBPROJECT #2: YELLOWSTONE CUTTHROAT TROUT MATURITY STUDIES

State of: Idaho Grant No.: F-73-R-23

Project No.: 2 Title: Native Species Investigations

Subproject #2: Yellowstone cutthroat trout maturity studies

Contract Period: July 1, 2000 to June 30, 2001

ABSTRACT

Age and length at sexual maturity for Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* (YCT) varies across their historical range, but the factors that influence this variation are poorly understood. We collected 610 YCT from 11 populations across southeastern Idaho from streams and rivers with a variety of physical characteristics to determine age and length at sexual maturity and other reproductive demographics. Sex ratio (male:female) ranged from 0.5:1 to 2.7:1, and over all streams combined was 1.2:1. The oldest YCT captured was 10 years old from the South Fork Snake River; most fish (90%) were between ages-2 and -4, and only three YCT (all from the South Fork Snake River) were older than age-7. South Fork Snake River YCT did not mature until 300 mm in length and five years in age, whereas YCT from other fluvial sites and resident sites began maturing at age 2-3 and lengths of 100-150 mm. Fish 100-250 mm in length were much more likely to be mature if they were resident rather than fluvial. Maturity transition point (MTP) for YCT ranged from 126-311 mm for females and 97-354 mm for males. The MTP was higher for females than males at all but one location. For both males and females, MTP was positively related to stream order and drainage area and negatively related to gradient. Maturity transition point was weakly correlated with elevation and most temperature metrics for male and female YCT. Using multiple regressions, stream width and gradient explained 91% and 72% of the variation in MTP for females and males, respectively; the best model for males included stream order and gradient and explained 79% of the variation in MTP. Our results enable prediction of MTP using readily derived physical data from streams and, as such, could be useful in estimating effective population size for populations of YCT.

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INTRODUCTION

Salmonids typically exhibit variation in adult life history patterns among populations (e.g., Ricker 1972; Scarnecchia 1983; Quinn and Unwin 1993; Hutchings 1996; Morita et al. 2000), reflecting differences in rearing conditions or genetic adaptations to local environments. Length and age at maturity are important aspects of the biology of salmonids, and to a degree define the reproductive potential for a given population. For Yellowstone cutthroat trout (YCT), length and age at sexual maturity vary across their historical range (Thurow et al. 1988; Varley and Gresswell 1988; Gresswell et al. 1994), presumably in response to biotic and abiotic factors such as stream productivity and size, migratory spawning pattern (i.e., fluvial or resident), and possibly genotypic variation, although genetic divergence in YCT is low (Allendorf and Leary 1988). Despite the knowledge that much variation exists in the reproductive life history traits of YCT among populations, the factors influencing this variation are poorly understood (Gresswell et al. 1997).

Yellowstone cutthroat trout populations have declined significantly from historical levels in terms of abundance and distribution (Thurow et al. 1988; Varley and Gresswell 1988; Kruse et al. 2000), and were recently petitioned to be listed under the Endangered Species Act. Despite a recent decision by the U.S. Fish and Wildlife Service not to list the subspecies (Office of the Federal Register, February 23, 2001, Vol. 66, No. 37, Pages 11244-11249), an evaluation of extinction risk for YCT would be valuable. One commonly used method of extinction risk assessment involves the calculation of effective population size (N_e) (e.g., Hedrick et al. 1995; Allendorf et al. 1997). Calculation of N_e using numerical abundance data requires knowledge about the number of breeders in a population and generation length (Waples 1990). Despite a few reviews discussing general sizes and ages at maturity for YCT (Thurow et al. 1988, Gresswell et al. 1994), we were unable to find an actual maturity schedule. The sparse existing data was typically based on spawners observed on redds or captured during migration, and did not address similar-sized fish that were not migrating or spawning. Kruse (1998) used 200 mm as the length of maturity when approximating effective population size in several Wyoming streams. However, this value was based on the same few observations above (Thurow et al. 1988; Gresswell et al. 1994) and on professional judgment, and we suspected it may be inaccurate for small stream populations. Before a broad application of age or length at sexual maturity can be made to existing presence/absence and abundance data for YCT in Idaho, a better understanding of when fish mature and what factors influence that maturity is necessary.

OBJECTIVES

1. Determine age and length at sexual maturity of YCT across their historical range in Idaho.

2. Determine fecundity, longevity, and sex ratios of YCT collected during the study.

3. Develop a model to predict YCT length at maturity based on easily obtained physical stream attributes.

METHODS

Using backpack- and boat-mounted electrofishing units, 499 YCT were collected from 10 streams in April 2000, and 111 YCT were collected from the South Fork Snake River in February and March 2001. Sample locations were distributed across private and public lands in southeastern Idaho, and included three streams from the Portneuf River drainage, one from the Teton River drainage, three from the Salt River drainage, and three from the South Fork Snake River drainage (Figure 3). Captured fish were transported directly to a freezer for storage.

At each collection site, we determined elevation from a U.S. Geological Survey (USGS) 1:24,000 topographic map using UTM coordinates obtained in the field. Stream order was determined at 1:100,000 scale using land status maps. Gradient was determined by tracing the distance between the contour lines above and below the site using the software package All Topo Maps Version 2.1 for Windows. Conductivity was measured with a hand-held conductivity meter accurate to ± 2%. Stream width was calculated from the average of 10 readings through the reach that was electrofished, except at the South Fork Snake River, where width was determined using aerial photographs. Drainage area was calculated using digitized USGS topographic maps and the ArcView® Version 3.1 software package. We deployed Onset Stowaway® thermographs at each site that recorded hourly water temperature throughout the summer months (Jun-Aug), from which average daily minimum, mean, and maximum temperatures were calculated. We classified each site as having YCT with either a resident or fluvial life history strategy based on professional knowledge of the systems.

Sacrificed fish were thawed and then measured for total length (nearest mm) and weight (nearest g) in the laboratory. Sagittal otoliths were removed and stored dry in vials, and scales were removed and spread on strips of paper, which were stored in envelopes. Age was determined primarily by viewing whole otoliths with a dissecting microscope. Due to the difficulty in interpreting ages for cutthroat trout from scales (Lentsch and Griffith 1987; Downs 1995), we read scales only for corroboratory assistance when age from otoliths was difficult to ascertain ($n = 14$). We prepared scales by pressing them on acetate slides with a heat press at 10,000 PSI and 110°C for 20-30 s and viewed them with a microfiche reader. Otoliths from several ($n = 15$) South Fork Snake River fish were particularly hazy and unusually difficult to read, and scales from the South Fork Snake River have been unreliable in the past (W. Schrader, IDFG, personal communication). To age these fish, we placed the otoliths in epoxy and sliced them with a Bronwill cross-cutting saw, roasted the otoliths on a hot plate, and viewed the sectioned otoliths with a compound microscope. All fish were considered one year old when they reached their first January.

Gender and maturity were determined by laboratory examination of the gonads, following the description of Downs et al. (1997). Eggs were counted from 77 mature females across all sites. Curvilinear (i.e., power function) regression equations to predict fecundity (F) from fish length (TL) were developed for all YCT combined, and for resident and fluvial life histories separately. To test for differences in regression slope between life histories, we log transformed the length and fecundity data to create a linear relationship, then used 95% confidence intervals around the difference between the regression coefficient estimates ($ß_1$ - $ß_2$). Because testing for a difference between y-intercepts ($\alpha_1 - \alpha_2$) is inappropriate (Zar 1996), we used *t*-tests to compare regression elevation estimates. To compare sex ratios at each site, we calculated 95% confidence intervals around the proportion of the population that was male or female, following Fleiss (1981).

To characterize a "maturity transition point" (MTP) between immature and mature fish within a stream, we used one of two methods. If there was no overlap between the largest immature and smallest mature fish, we selected the midpoint between the lengths of these two fish. If there was overlap, we related fish length to maturity using logistic regression, using a binary dependent variable (0 = immature, 1 = mature), and selected the MTP as the fish length at which the probability of being mature was equal to 0.5. At each stream and for each sex, the adequacy of the logistic regression model was evaluated by McFadden's Rho² value. McFadden's Rho² is a transformation of the likelihood-ratio (LR) statistic (SYSTAT 1998) and mimics an r^2 value, though scores tend to be much lower; values between 0.20 and 0.40 are considered very satisfactory (Hensher and Johnson 1981). Since males tended to mature at a smaller size than females, we determined MTP separately for males and females. If there was overlap between immature and mature fish, and a suitable logistic regression could not be fit to the data for a site, we did not estimate MTP.

We examined the influence of stream attributes on YCT MTP using simple correlation analysis and constructed a predictive model using linear regression analysis. Before performing regression analysis, we removed from consideration any combination of independent variables with bivariate correlations greater than 0.70 (Tabachnick and Fidell 1989). If two independent variables were highly correlated, we attempted to remove the variable that had the weakest relationship with MTP. We attempted to use variables that would be easiest to obtain in the field or directly from maps, or that were in existing databases.

The South Fork Snake River was an order of magnitude wider and two orders of magnitude larger in drainage area than any other sites. We therefore investigated correlations between stream variables and MTP and developed predictive models both with and without the South Fork Snake River included in the analysis.

RESULTS

The physical stream attributes and characteristics varied greatly between sites (Table 3); stream order ranged from 1st-6th, conductivity ranged from 183-652 µS/cm, stream width ranged from 1.7-79 m, elevation ranged from 1640 to 2091 m, and drainage area ranged from 7.9-13,527 km². Four streams were classified as supporting resident life history forms of YCT, while seven were classified as supporting fluvial populations of YCT.

A total of 610 YCT was captured from 11 locations throughout southeastern Idaho. Of these, sex could not be determined for 91 fish (average 77.6 mm, range 50-112 mm); these fish were not included in further analysis. Most fish whose sex could be determined were age-2 (28.7%), -3 (49.0%), or -4 (12.6%), and only three fish (0.6%) in the entire study were older than age-7. The oldest YCT captured was 10 years old from the South Fork Snake River (Table 4).

In the South Fork Snake River, only 4.8% of YCT less than 300 mm in length were mature. In contrast, YCT less than 300 mm in length at other fluvial sites and resident sites were mature 22.4% and 50.3% of the time, respectively (Figure 4). Similarly, only 4.5% of South Fork Snake River YCT less than age-5 were mature, compared to 26.8% and 52.7% maturity for ages-2-4 YCT from other fluvial and resident sites, respectively (Figure 5). Within most age and 50 mm size classes, percent maturity was greater for resident than fluvial YCT (Figures 4 and 5).

Sex ratio (male:female) varied from 0.5:1 to 2.7:1 among sites; for all fish combined, sex ratio was 1.2:1 (Table 4). Males outnumbered females at eight of 11 sites, but confidence limits around the estimated proportion of the population that was male or female overlapped at all but three locations.

There was a strong relationship between fish length and fecundity across all sites (r^2 = 0.857; n = 77; Figure 6). However, there was little overlap in fish lengths between the South Fork Snake River and all other sites, and the relationship between fish length and fecundity for South Fork Snake River fish alone ($F = 0.0026 * TL^{2.2255}$) was much weaker (r^2 = 0.218; n = 37) than for all resident fish ($F = 0.0006 * TL^{2.5124}$; r^2 = 0.821; n = 26) or for all other fluvial fish ($F = 0.00009 * TL^{2.8266}$; r^2 = 0.629; n = 14). We found no evidence of a difference between resident and fluvial regression equations (using log transformed data) in terms of regression coefficients ($ß_1 - ß_2 = 0.32 \pm 3.47$) or y-intercepts ($t$ = 1.770; P = 0.088). We did not test whether the regression equation for South Fork Snake River fish differed from other fluvial fish or from resident fish because of the lack of data overlap in fish lengths.

Maturity transition point was determined by logistic regression at three sites for females and seven sites for males, whereas there was no overlap between immature and mature fish at six sites for females and two sites for males (Table 5; Figure 7). Maturity transition point could not be determined for females at NF Rapid Creek or males at lower Crow Creek. Maturity transition point was lower on average (Paired *t*-test, t = 2.574; n = 9, P = 0.033) for males (197.1 mm ± 54.0) than for females (227.7 mm ± 41.8). Maturity transition point was also lower at sites with resident YCT than fluvial YCT. For males, mean MTP was 158 mm (range 97-236 mm) for resident fish and 214 mm (range 173-354 mm) for fluvial fish; without South Fork Snake River fish, mean fluvial MTP for males was 186 mm (range 173-214 mm). For females, mean (range) MTP for resident and fluvial fish were 194 mm (range 126-261 mm) and 252 mm (range 193-311 mm), respectively; without South Fork Snake River fish, mean MTP for female fluvial fish was 242 mm (range 193-263 mm).

For both males and females, MTP was positively related to stream order and drainage area and negatively related to gradient (Table 6). The above relationships were applicable with or without inclusion of South Fork Snake River data. The correlation between MTP and conductivity increased for both males and females when South Fork Snake River data were removed. Elevation and most water temperature metrics were weakly correlated with MTP for both males and females. Multicollinearity comparisons involving stream width and drainage area were skewed high because values for the South Fork Snake River were orders of magnitude higher than for other sites. Without including this data, we still found multicollinearity between stream width and stream order (r = 0.74), stream width and drainage area (r = 0.80), and between all temperature metrics.

Stream gradient and stream order were the easiest variables to obtain, and explained much of the variation in MTP. With South Fork Snake River data included in the analysis, gradient and stream order explained 87% of the variation in MTP for females (Table 7). For males, stream order explained 87% of the variation in MTP, and adding gradient did not improve the model. Without the South Fork Snake River, models including gradient and stream order explained 83% and 73% of the variation in MTP for females and males, respectively (Table 7).

DISCUSSION

Our results indicate that certain physical attributes of streams correlate well with the length at which YCT mature. Our finding that stream size (i.e., width, drainage area, and stream order) was directly related to length at maturity concurs with Gresswell et al. (1997), who reported that two-thirds of the variation in average length of YCT spawners from Yellowstone Lake was explained by mean aspect and drainage area. Neither conductivity, an index of stream productivity (Northcote and Larkin 1956; Ryder 1965), nor water temperature showed any consistently strong relationship to MTP, although they have been shown to be related to growth (McFadden and Cooper 1962; Schill 1991). Maturity transition point appears to be more related to the physical characteristics of a stream which dictate such things as living space, the size of substrate in which fish must dig redds, etc., than to the physiochemical characteristics of the stream.

We do not wish to imply, however, that variables we measured that showed no relationship to MTP necessarily have no influence on fish maturation. For example, temperature metrics such as accumulated thermal units or degree days, which would have incorporated the time of year that YCT gonads ripen, may have correlated better with MTP than the metrics we calculated. Additionally, we measured temperature over only one summer, but most mature fish we encountered went through at least two years of growth. Moreover, a host of other factors that we did not examine, such as fish density, angling pressure, and migration distance, can influence reproductive life history traits (Ricker 1981; Holtby and Healey 1986; Peterman et al. 1986; Hegge et al. 1991), and may have had an influence on MTP for which we did not account. In addition, there could be subtle interactions between factors that affect MTP that our study was not designed to detect. Scarnecchia (1983) discussed the dangers of viewing variation in a particular life history trait such as age or length at maturity as an isolated response to one or two environmental factors, and argued that such traits are best viewed in the context of the entire life history pattern of a species. Nevertheless, the models we developed are simple and explained much of the variation in MTP for smaller streams and rivers.

The South Fork Snake River YCT population differed from fish from other locations in almost every aspect, including fecundity, longevity, age at maturity, length at maturity, and the fact that females matured earlier than males. The latter difference was probably due to a discord in iteroparity between genders. Several large YCT that were captured in the South Fork Snake River were not ripe, probably because they were skipping a year of spawning. We believe that most of the immature South Fork Snake River fish 350-400 mm in length had spawned previously and were not truly immature fish.

Because of these differences, and the fact that the South Fork Snake River was our only data point from a large system, and despite the strength of the predictive models that include South Fork Snake River data, we are cautious about applying our results (and equations) to larger rivers in Idaho without other supportive information. However, within the constraints of the models that exclude South Fork Snake River data, the equations we developed should be applicable to a wide variety of locations when predicting at what length YCT mature. Verification of the fit of the model to data from one or more untested streams would further substantiate our results. Additional sampling may be necessary before applying our model to large systems, but population status of other appropriately sized water in Idaho may preclude such efforts.

We found that sites containing resident YCT had lower MTPs than did sites with fluvial fish, with the main difference occurring between 100-250 mm (Figure 4). In this size range, resident females were nearly ten times more likely to be mature than fluvial females, and resident males were twice as likely as fluvial males to be mature. Our study design may not have allowed us to fully assess differences between resident and fluvial life histories. For example, at our fluvial sites, there is no way of knowing if some of the fish we captured were actually resident fish. The interaction of resident and fluvial behaviors within a particular system is a subject that has been little studied.

Male YCT outnumbered females at most of the sites in our study. However, sample size was relatively low for most study sites (greater than 60 fish at only one location), and confidence limits around sex ratios overlapped at eight of 11 sites. Consequently, our data suggest that sex ratio in general did not differ from 1:1. Thurow et al. (1988) and Gresswell et al. (1997) both found that female YCT were more numerous than males in migratory spawning populations. Differences in sex ratios typically indicate a mortality differential between sexes, usually due to angling effects (McFadden 1961), a shorter life span resulting from earlier attainment of sexual maturity (Hoar 1957), or differential energy expenditures during migration or spawning. Males did mature earlier than females at almost every location in our study, which is common in salmonid populations (McFadden 1961; Lachance and Magnan 1990), but such a difference should result in a higher mortality rate in males and thus a skew toward having more females in the population unless there is some genetic basis for production of more males. Longevity between males and females was essentially equal in our study, providing further evidence that there was no difference in mortality between genders or in the sex ratio.

Our results suggest that it should be possible to predict YCT length at maturity in a variety of systems based on physical stream attributes that are easily obtained. The results could be used to approximate the effective population size for YCT in waters where fish abundance and size structure data are available. The models presented here will permit more accurate calculations of effective population size than past efforts.

RECOMMENDATION

1. Where sufficient data exist, estimate effective population size for Idaho YCT by combining MTP regression results with population data.

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Table 3. Stream attributes for the study sites in southeastern Idaho. Stream number corresponds to Figure 3. NA refers to Not Available.

Stream no.	Location	Elevation (m)	Stream order (1:100,000)	Conductivity (µS/cm)	Gradient (%)	Stream width (m)	Drainage area (km²)	Life history	Summer (Jun - Aug) water temperature (°C) Min	Avg	Max
1	Harkness Creek	1707	1	295	6.3	1.7	7.9	Resident	9.0	10.9	14.0
2	Spring Creek	2042	1	415	2.0	2.4	6.8	Fluvial	10.5	13.7	17.2
3	NF Rapid Creek	1561	2	452	1.2	3.1	34.7	Resident	12.9	16.1	19.3
4	Upper Crow Creek	2091	2	440	1.7	5.2	36.5	Fluvial	NA	NA	NA
5	Canyon Creek	1798	2	183	0.9	4.4	148.1	Fluvial	11.5	15.5	19.8
6	W. Pine Creek	1768	2	332	1.5	3.2	23.8	Fluvial	6.8	10.4	15.3
7	Dempsey Creek	1670	2	285	2.8	3.6	49.0	Resident	10.3	14.8	20.0
8	Lower Crow Creek	1984	3	502	0.4	5.4	143.3	Fluvial	12.8	13.9	15.1
9	Tincup Creek	1856	3	358	1.1	5.8	104.8	Fluvial	12.3	15.0	18.3
10	Fall Creek	1664	4	652	0.8	6.0	193.4	Resident	NA	NA	NA
11	SF Snake River	1640	6	239	0.2	79	13527	Fluvial	11.4[a]	12.1[a]	12.9[a]

[a] Data from 1996

Table 4. Sex ratio and longevity of Yellowstone cutthroat trout across study sites in southeastern Idaho. Data includes all fish (immature and mature) whose sex could be determined.

Location	No. of males	No. of females	Sex ratio (M:F)	Maximum age Male	Maximum age Female
Harkness Creek	19	14	1.4:1	4	4
Spring Creek	15	14	1.1:1	4	4
NF Rapid Creek	22	20	1.1:1	5	4
Upper Crow Creek	26	24	1.1:1	3	4
Canyon Creek	37	22	1.7:1*	5	4
W. Pine Creek	32	12	2.7:1*	6	6
Dempsey Creek	24	19	1.3:1	4	4
Lower Crow Creek	10	19	0.5:1	4	5
Tincup Creek	38	19	2.0:1*	5	5
Fall Creek	25	28	0.9:1	5	7
SF Snake River	36	44	0.8:1	10	8
Overall	284	235	1.2:1		

* Sites where 95% confidence limits did not overlap

Table 5. Results of logistic regression models (McFadden's Rho²) and sizes of largest immature and smallest mature fish used to estimate maturity transition points for male and female Yellowstone cutthroat trout in southeastern Idaho. NA indicates Not Applicable or Available.

Location	Sex	n	McFadden's Rho²	Largest immature	Smallest mature	Maturity transition point
Harkness Creek	Male	19	NA	NA	97	97
	Female	14	0.07	150	112	126
Spring Creek	Male	15	NA	178	181	180
	Female	14	NA	175	212	193
NF Rapid Creek	Male	22	0.21	190	136	145
	Female	20	0.00	258	127	NA
Upper Crow Creek	Male	26	0.19	217	127	181
	Female	24	NA	228	257	242
Canyon Creek	Male	37	0.52	175	133	173
	Female	22	NA	207	275	257
W. Pine Creek	Male	32	0.51	240	178	184
	Female	12	0.76	202	200	201
Dempsey Creek	Male	24	0.28	198	125	155
	Female	19	NA	192	199	195
Lower Crow Creek	Male	10	0.02	297	181	NA
	Female	19	NA	277	319	298
Tincup Creek	Male	38	0.31	254	161	214
	Female	19	0.37	271	232	263
Fall Creek	Male	25	0.39	274	213	236
	Female	28	0.35	255	202	261
SF Snake River	Male	36	0.40	398	198	354
	Female	44	0.46	382	173	311

Table 6. Correlations (*r*) between stream attributes and maturity transition points for male and female Yellowstone cutthroat trout in southeastern Idaho.

	With SF Snake River data		Without SF Snake River data	
Variable	Female	Male	Female	Male
Stream order (1:100,000 scale)	0.79	0.93	0.77	0.79
Width (m)	0.53	0.86	0.91	0.82
Drainage area (km^2)	0.49	0.84	0.79	0.66
Conductivity (µS/cm)	0.18	< 0.01	0.42	0.53
Jun-Aug average daily maximum temperature (°C)	- 0.08	- 0.42	0.30	0.37
Jun-Aug average daily mean temperature (°C)	0.39	- 0.11	0.62	0.29
Jun-Aug average daily minimum temperature (°C)	0.69	0.23	0.71	0.18
Elevation (m)	0.07	- 0.11	0.32	0.24
Gradient (%)	- 0.90	- 0.67	- 0.90	- 0.80

Table 7. Regression equations relating stream attributes to maturity transition point (MTP) for Yellowstone cutthroat trout in southeastern Idaho. G = gradient, SO = stream order.

Equation	SE	r^2 or R^2
With South Fork Snake River data		
Females		
MTP = (29.40 * SO) + 158.26	36.23	0.63
MTP = (- 28.53 * G) + 285.21	25.44	0.82
MTP = (13.81 * SO) - (21.18 * G) + 236.29	20.05	0.87
Males		
MTP = (42.22 * SO) + 86.35	26.02	0.87
MTP = (- 27.71 * G) + 243.16	51.90	0.49
MTP = (36.42 * SO) - (8.46 * G) + 116.50	24.50	0.87
Without South Fork Snake River data		
Females		
MTP = (41.24 * SO) + 134.59	35.50	0.59
MTP = (- 26.38 * G) + 277.51	23.77	0.82
MTP = (16.66 * SO) - (20.43 * G) + 228.92	21.44	0.83
Males		
MTP = (34.13 * SO) + 101.84	26.01	0.63
MTP = (- 18.65 * G) + 211.82	25.53	0.64
MTP = (21.00 * SO) - (11.85 * G) + 153.65	20.88	0.73

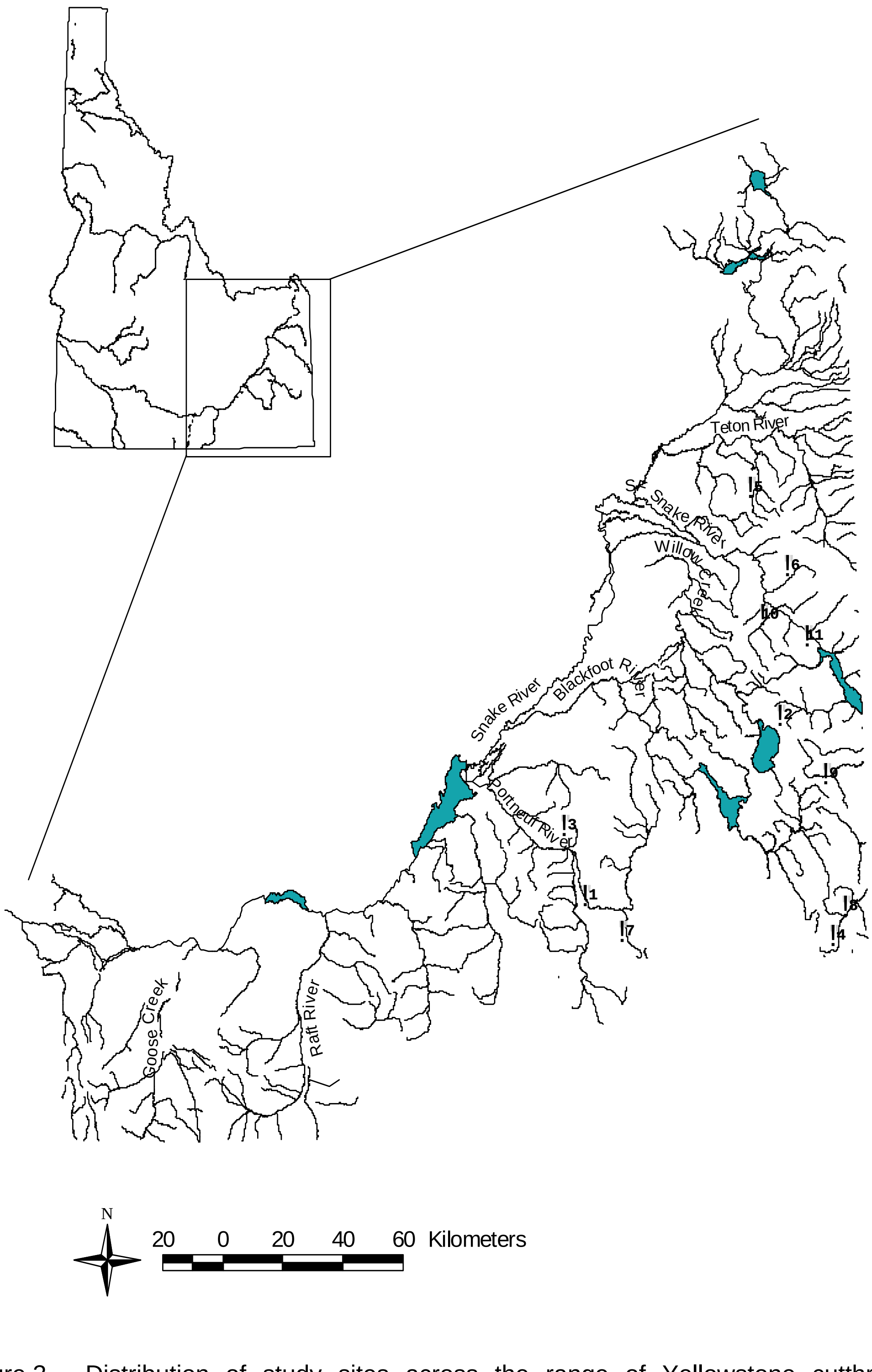

Figure 3. Distribution of study sites across the range of Yellowstone cutthroat trout in southeastern Idaho. Numbers correspond to Table 3.

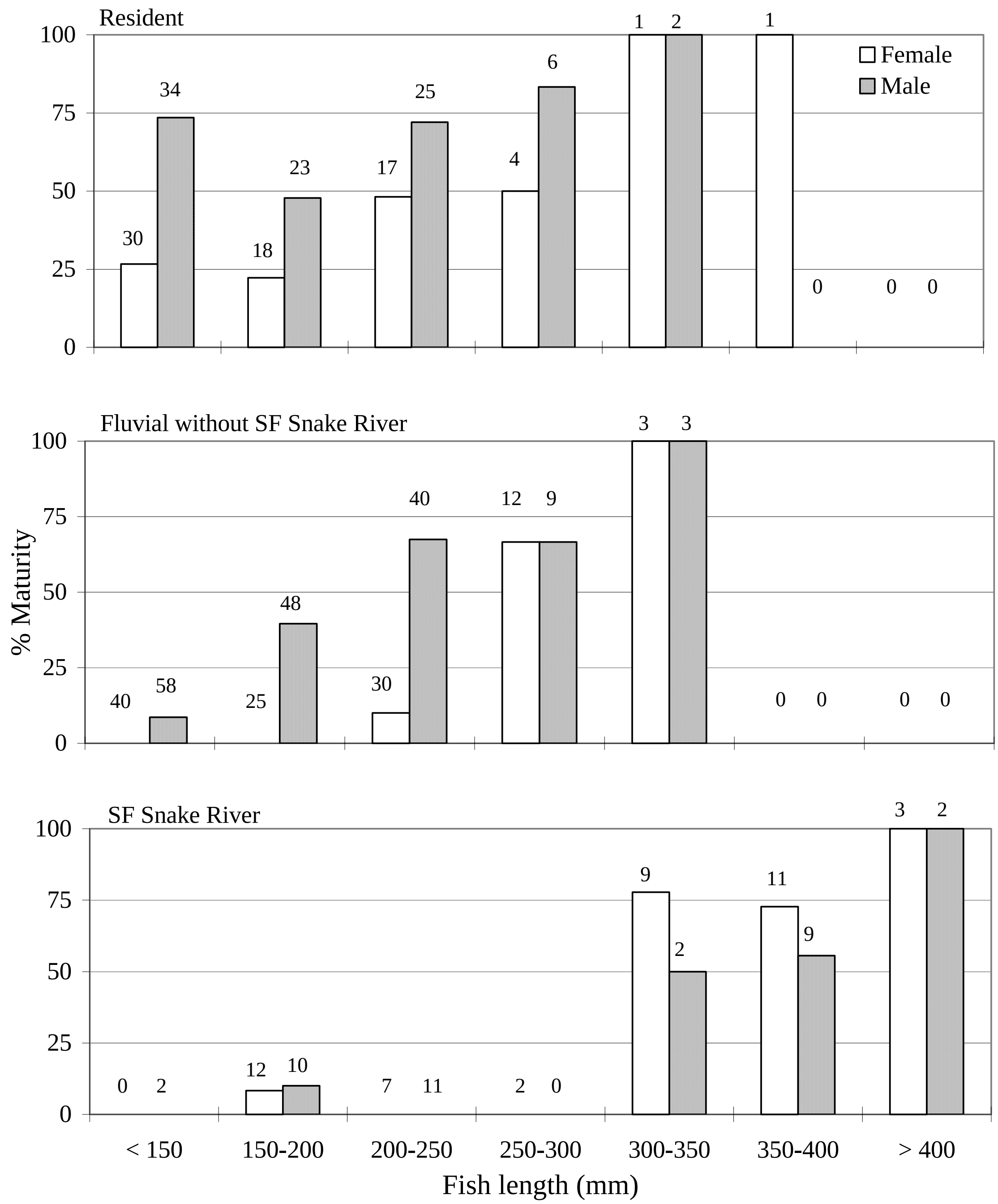

Figure 4. Proportions of male and female Yellowstone cutthroat trout mature at length in southeastern Idaho. Numbers above bars indicate sample size.

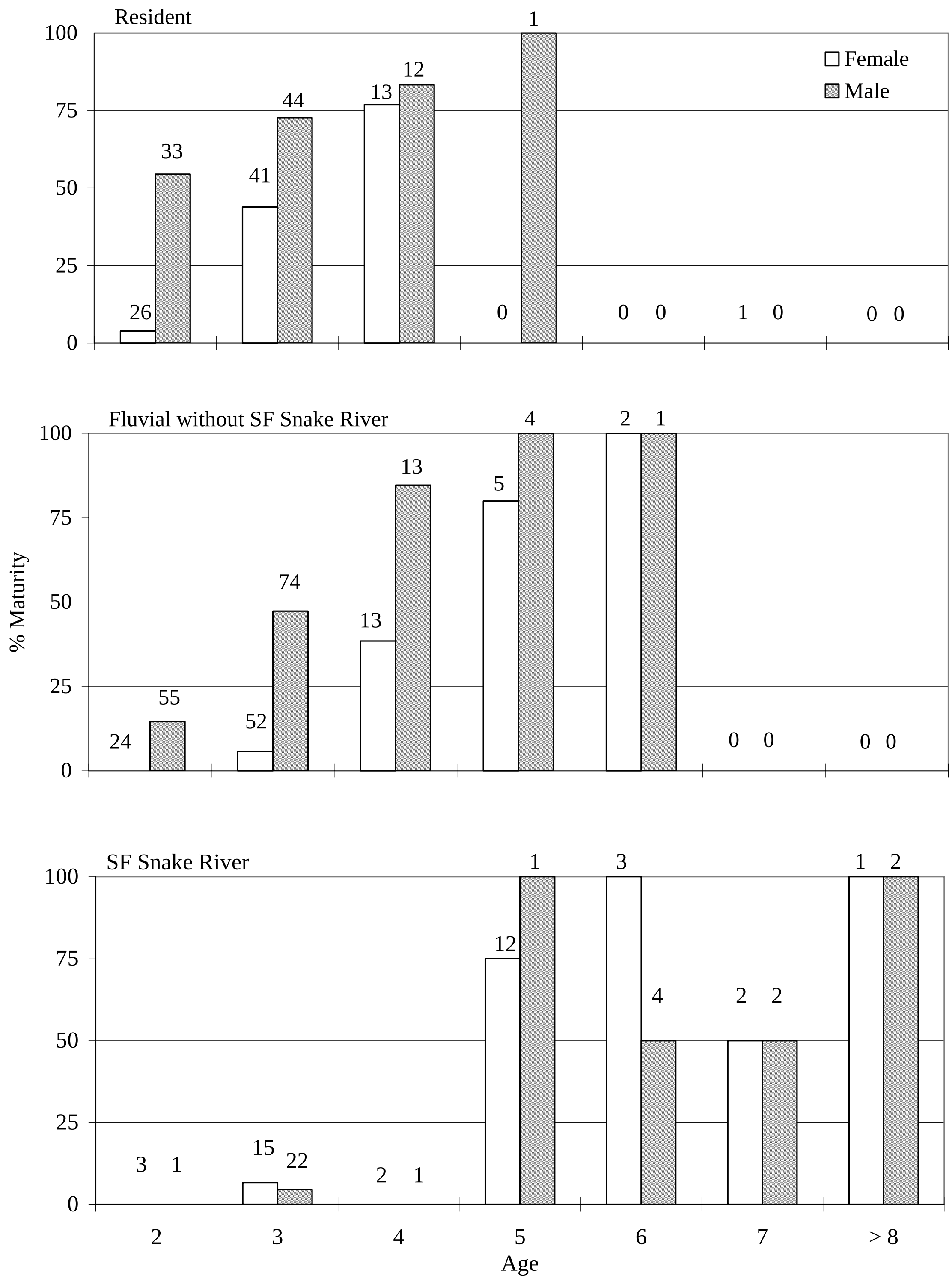

Figure 5. Proportions of male and female Yellowstone cutthroat trout mature at age in southeastern Idaho. Numbers above bars indicate sample size.

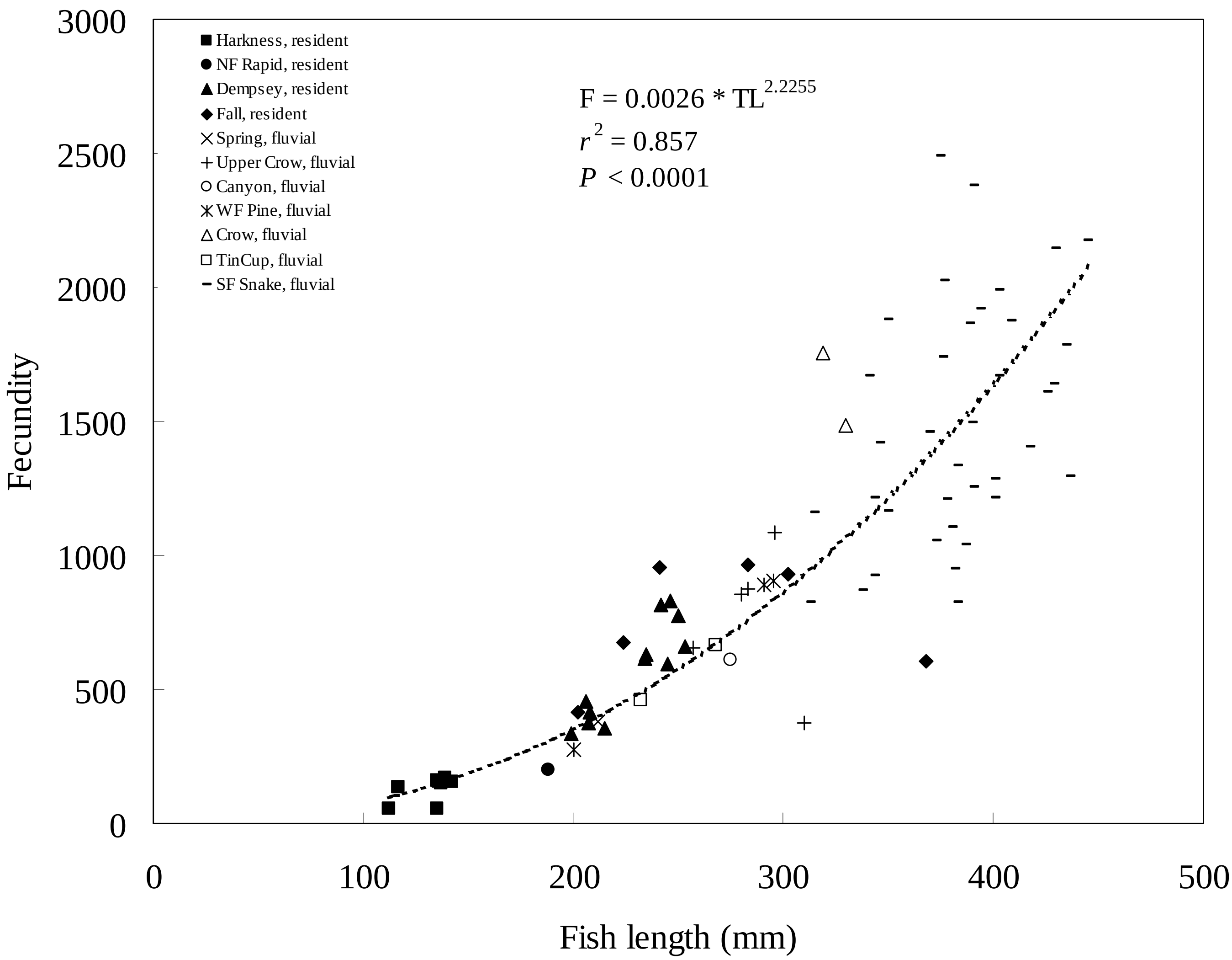

Figure 6. Relationship between fish length and fecundity for Yellowstone cutthroat trout in southeastern Idaho.

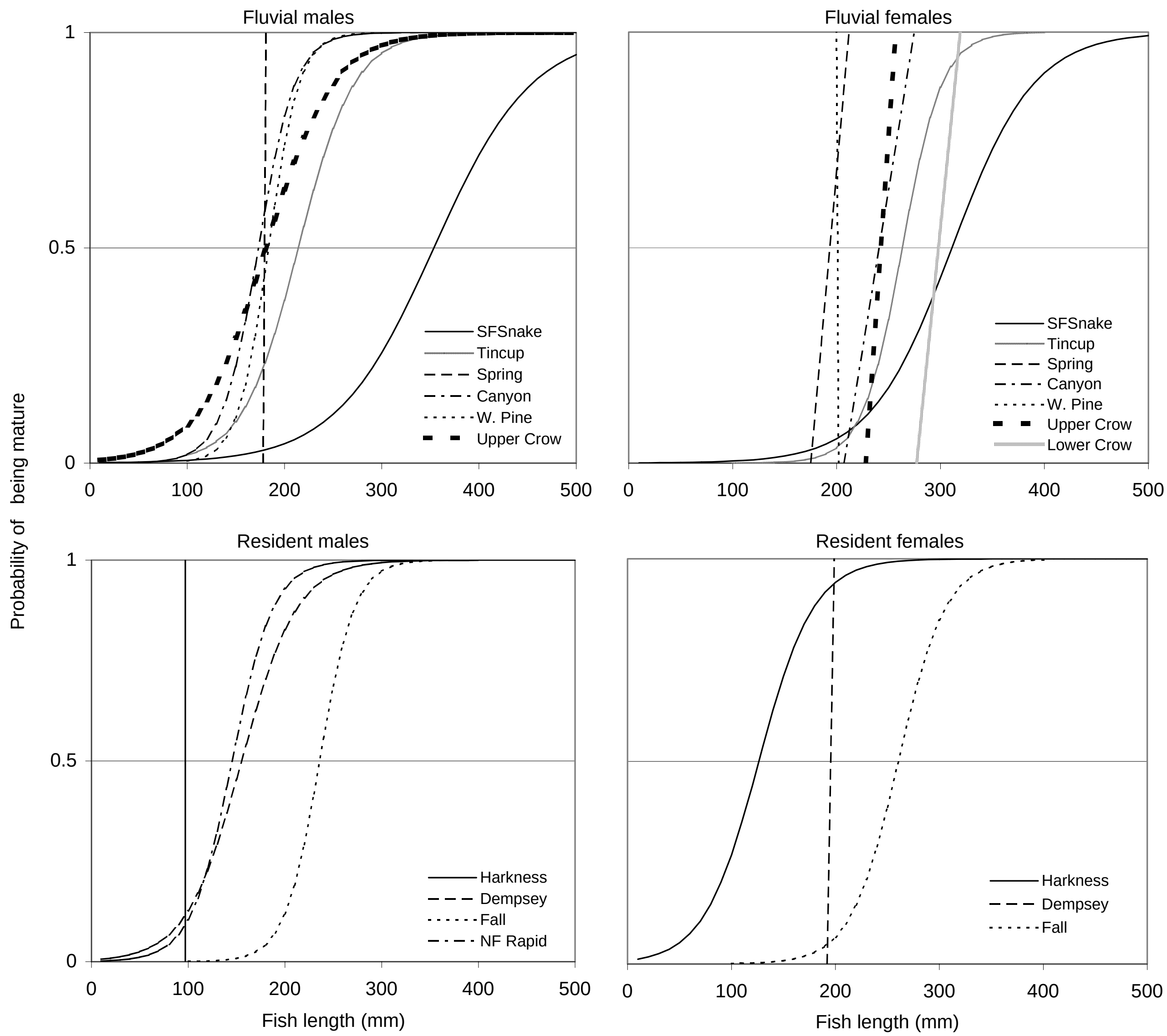

Figure 7. Maturity transition points (MTP) for male and female Yellowstone cutthroat trout in southeastern Idaho. MTP (where the probability of being mature is 0.5) was determined by logistic regression (sigmoid curves) unless there was no overlap in the largest immature and smallest mature fish at a given site (straight lines).

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